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APPLICATION OF ADVANCED FRACTURE MECHANICS TECHNOLOGY TO ENSURE--ETC(U)
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APPLICATION OF ADVANCED FRACTURE MECHANICS
TECHNOLOGY TO ENSURE STRUCTURAL RELIABILITY
IN CRITICAL TITANIUM STRUCTURES

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Materials Engineering Department

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Introduction

The assurance of safe and reliable structural performance of critical components, structures, and equipment subjected to adverse loading conditions has always been a matter of vital concern to both the U.S. Navy and the Westinghouse Electric Corporation. The capability to conduct appropriate structural integrity analyses takes on an added importance when new equipment, designs, materials, inspections and fabrication procedures are concerned.

In these situations there is little or no service experience to rely upon; hence, a thorough structural integrity analysis, incorporating all of the interacting factors must be included as a major element in the overall plan. Such analyses should take advantage of the most advanced technology areas that are applicable to the situation of concern; in this case modern fracture mechanics technology offers a unique and directly applicable capability.

Early developments of fracture mechanics focused on plane-strain or essentially linear elastic fracture conditions (LEFM) and on relatively high strength brittle material such as aircraft structures, missile cases, gun tubes, etc. Soon the technology was extended to include fatigue and stress corrosion crack propagation. Later on, because of the recognized limitations in the applicability of LEFM, effort was devoted to extend the fracture mechanics technology to encompass situations involving considerably more plasticity than is permissible under LEFM conditions. As a result the break through came in the form of the path independent J-integral, a field parameter analogous to K in LEFM. The general usefulness of the technology has thus been extended to a much broader spectrum of applications and materials: lower strength, higher localized stress regions, low cycle fatigue and creep controlled crack growth. Even more recently, the technology has taken another major step forward with the advent of J resistance curves, tearing modulus concepts and tearing instability models. These recent developments offer the capability to predict the permissible amounts of stable crack growth in the ductile temperature regime, and the eventual instability conditions

for the catastrophic failure of the structure by ductile tearing under fully plastic conditions. More importantly these recent advances in technology offer the promise of enabling the design of structures and selection of materials so as to avoid any possibility of failure due to ductile tearing instability.

In short, fracture mechanics provides engineers with a powerful new tool for more effective design pertaining to structural reliability; it therefore seems logical that it should be an important part of the Navy's titanium program.

Objectives

The overall objective of this program is to assist the Navy in developing and applying advanced fracture mechanics technology to ensure structural integrity in critical applications of titanium alloys. To achieve this the following specific objectives are included:

1) Development of methods for assessing Structural Reliability —

Different methods to assess structural reliability will be considered and the best possible choice will be proposed. This method should include the latest in fracture mechanics methodology.

2) Responding to Specific Navy Concerns — —

Should the Navy have at any given moment a specific concern, it could be included in the present program if budget time and general scope permits.

3) Recommendation of Methods for Implementing Structural Reliability Procedures — —

Once the overall methodology has been established, recommendations for implementing specific procedures will be made.

Approach

The program consists basically of two phases.

Phase I. Assimilation of pertinent information and data

A comprehensive review is to be conducted to assimilate the currently available information and data needed for applying advanced fracture mechanics technology to structural reliability analyses of critical components or structures using titanium alloys.



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Phase II - Structural Integrity Analyses

Detailed structural integrity analyses of specific models of components or structures will be conducted using the best available input information and data and the most advanced state-of-the-art fracture mechanics concepts.

Technical Progress

Numerous meetings were held with Navy personnel in order to conduct a survey to identify areas of concern and the experimental data needed for the structural analysis. The mentioned areas cover a broad spectrum regarding loading conditions material behavior, fabrication procedures, weldments and structural integrity. It was anticipated that some data needed might not be available in which case recommendations were to be made regarding the data gathering and/or critical tests for the specific needs.

The survey revealed that the concern and questions raised were not quantitative but rather of a qualitative nature and among people of different technical functions there was frequently a difference in interests, concerns and priorities. The survey showed that many of the points of concern need experimental work and also that some of the issues are still a subject of basic research in areas where fracture mechanics is much more advanced and has been extensively used.

As a starting point of Phase II - Structural Reliability Analysis - a flow chart was constructed for accident and service conditions. The chart shows a simple way of deciding upon different issues, a justification for doing so and a way of improving the analysis.

A way of implementing the stability analysis methodology was explained in detail and a new design philosophy for assessing stable crack propagation under load controlled condition was developed.

A model example provided by the Navy, with cracks at different location is being analyzed in terms of resistance to crack growth by means of the J-integral, and in terms of the tendency for instability using the tearing modulus theory. The material properties used are experimental data also provided by the Navy.

An attempt is being made to introduce in the analysis some recent developments in the elastic plastic fracture area, regarding possible dependence of the J-R on specimen geometry. The results have been so far very encouraging.

Reporting

Two reports have been issued

80-9D3-TTNAV-R1	20 November 1980
81-9D7-TTNAV-R1	15 June 1981

General

A request has been recently made by W, accepted by the Navy to extend the period of performance 6 months from a September 30, 1981 to a March 30, 1982 termination date. The tasks remaining in Phase II along with an approximate schedule follows.

1. Analysis of the structural model provided by DTNSRDC, Carderock, with various crack locations and for conventional loading.
2. Incorporation of dynamic loading considerations into the analysis of this structural model.
3. Incorporation of mode II fracture considerations into the above analysis.
4. Incorporation of new approaches to elastic-plastic fracture characterization into the above analysis.

5. Reporting:

The approximate schedule is given in the following table:

